FNAL, Technical Division
TD-06-053

August 30, 2006

RESULTS OF COMPRESSION AND TENSILE TESTS OF RF CAVITY USING THE INSTRON

V. Khalatian.

I. Introduction

There is broad agreement in the High Energy Physics community that a linear collider is of fundamental importance for the future development of Particle Physics, and is in many respects complementary to the Large Hadron Collider and should be built as the next accelerator facility. As LHC development is at it's final steps, a collaborations on scientists is competing conceptual designs for the next step in High Energy Physics- International Linear Collider (ILC). 9-cell Niobium Cavity is an integral part of the ILC project. This cavity is cooled by superfluid Helium to T=2K and operating at L-band frequency (1.3 GHz). This design proved itself useful at TESLA. Because the power dissipation in the cavity walls is extremely small, the accelerating field can be produced with long, low peak power RF-pulses; this results in a high RF to beam power transfer efficiency, allowing a high average beam power while keeping the electrical power consumption within acceptable limits.

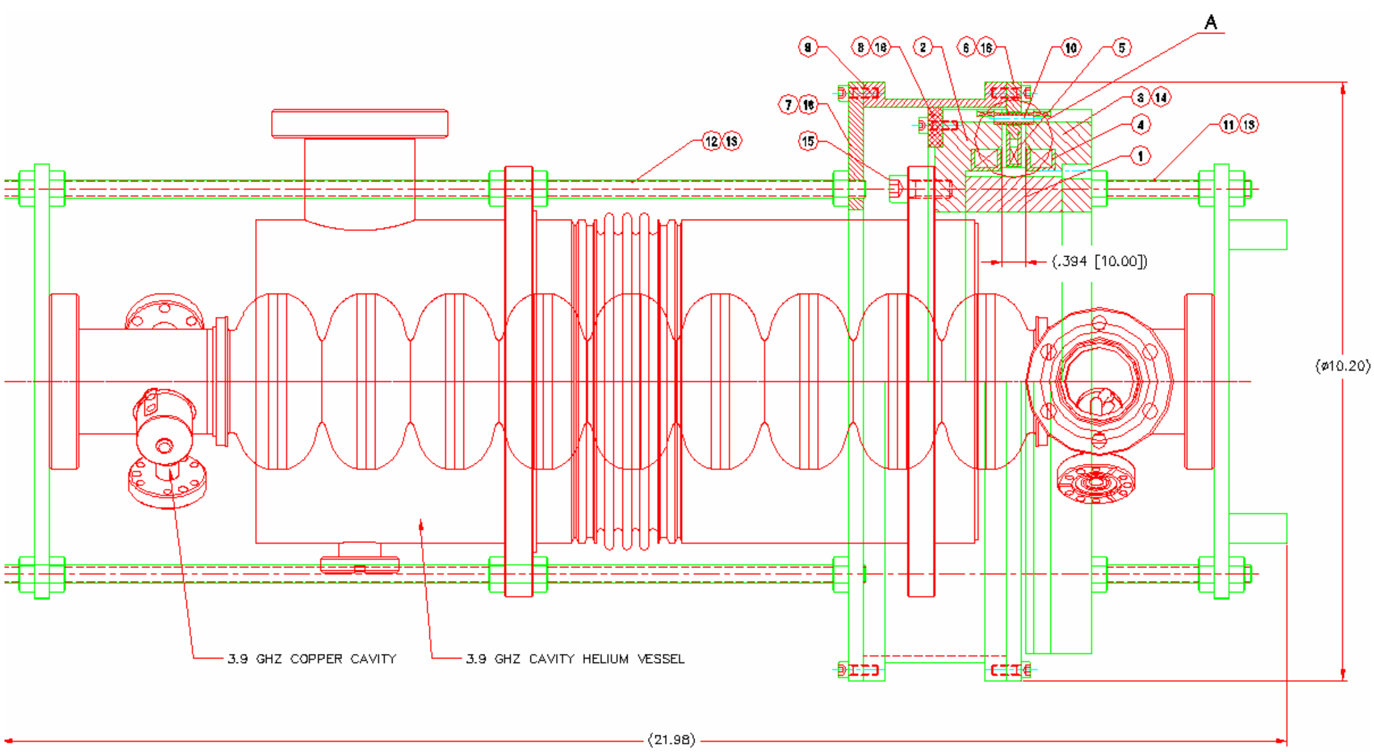


Fig. 1 ACAD drawing of the 9-cell Niobium Cavity

16		SCREW CAP SOC HD #8-32x.50 SST	32
15		SCREW CAP SOC HD 5/16-18x.75 SST	6
14		SCREW CAP SOC HD 1/4-20x.75 SST	12
13		HEX NUT 5/16-18 SST	48
12		FULL THREADED ROD 5/16-18 15.0"Lg SST	6
11		FULL THREADED ROD 5/16-18 3.5"Lg SST	6
10		TUBE .195"OD, .12"ID, .67"Lg SST	1
9	MC-443238	RING CONNECTOR WELDMENT	1
8	MB-443237	TEFLON RING	1
7	MB-443236	RING	1
6	MB-443235	CENTRAL BOBBIN RING	1
5	MB-443234	CENTRAL BOBBIN	1
4	MB-443233	BOBBIN	2
3	MC-443232	YOKE 2	1
2	MC-443231	YOKE 1	1
1	MB-443230	CENTRAL YOKE	1
ITEM	PART NO.	DESCRIPTION OR SIZE	QTY.
PARTS LIST			

II. Measurements of stiffness coefficient of 3.9 GHz cavity

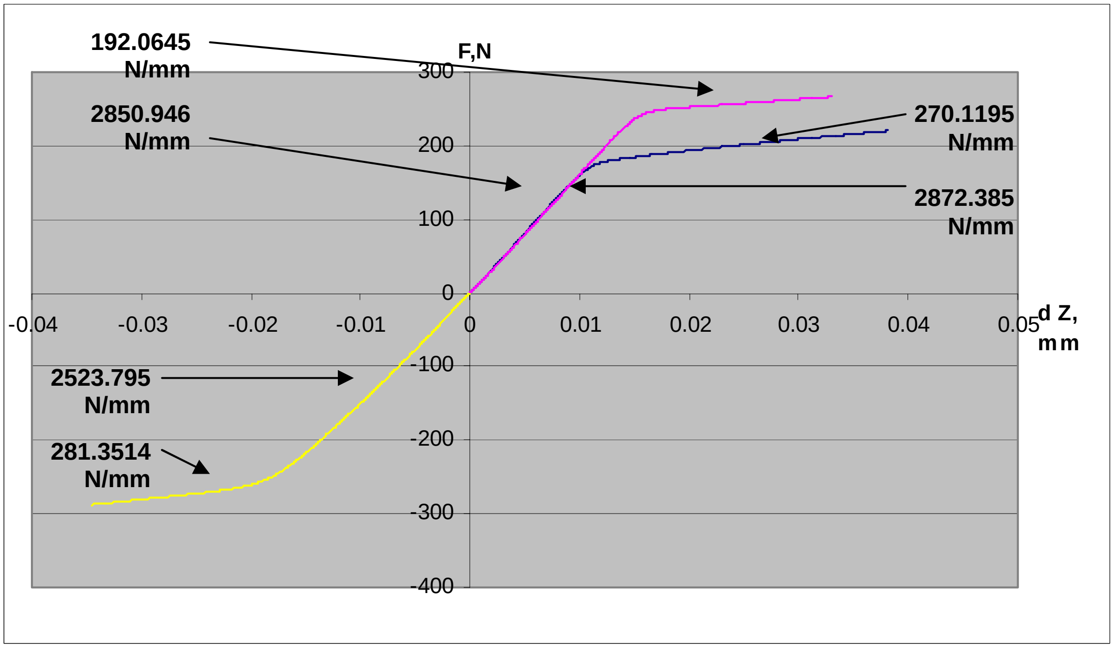
We have been working on a similar structure of a 9-cell 3d harmonic RF Cavity for TTF upgrade and Ao photo injector, instead of ILC Cavity, we are using a 9-cell copper cavity manufactured by Fermilab. Niobium and brass have similar qualities and coefficients when it comes to metal strength. Copper cavity is easier to work with and is cheaper then the niobium counterpart. In ILC, the cavity is a crucial component used for acceleration of electrons and positrons. Cavity is cooled down with liquid helium.

Fig. 2 TM_{010} mode "3rd Harmonic"

Our task was to run Compression and Tensile tests on the copper cavity to determine chops and changes in coefficient of inclemency and stiffness of the cavity. It is important that the cavity does not deform or go though major changes when put under pressure under extreme temperatures. In order to do that, we took the brass cavity (without the RF Tuner) and put it into the Instron.

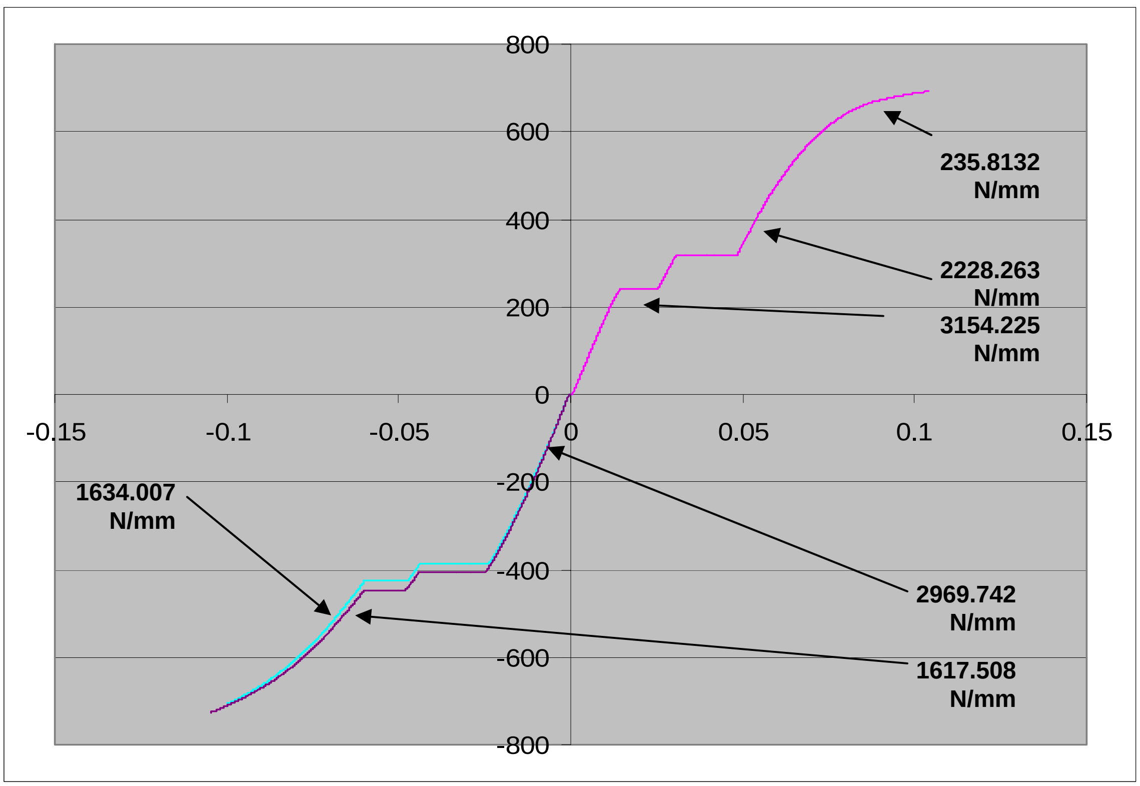
Fig. 3 Cavity in the Instron

We ran a set of tests at normal room temperature. We had 3 trials for both compression and tensile, moving the cavity in and out around 2 mm. Normal temperatures were used to compare the data to attribution of metal under liquid Helium temperature. The graphs and results are presented in the graph below.



Graph 1

This graph shows the dependence between Force and deformation in normal conditions. As we see the stiffness coefficient of cavity is about 2750 N/mm in elastic deformations and is about 250 N/mm in elastic-plastic deformations.



Here we can see the dependence between Force and deformation in liquid nitrogen at 70 degrees of Kelvin. The stiffness coefficient of cavity in elastic deformations changed from 2750 N/mm to 3062 N/mm. This happened because of reduction of temperature. In elastic-plastic deformations the stiffness coefficient of cavity was the same.

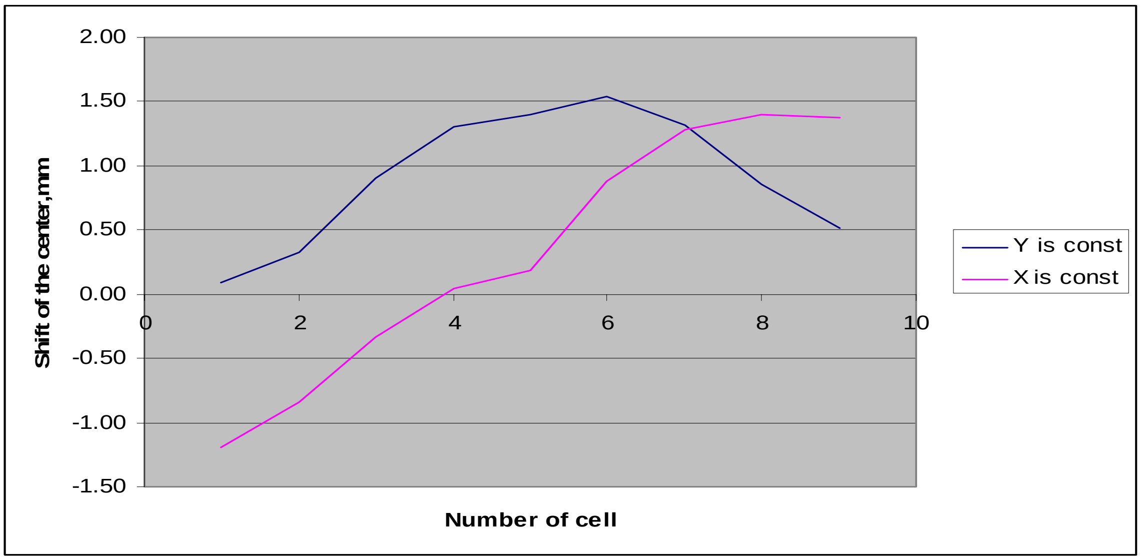
III. Measuring dumbbells

Every niobium dumbbell was produced with little asperity. To determine this defects we passed electromagnetic wave through the dumbbell then turned over it and passed wave again .Then made similar actions but with disturb element. Always we measured 0-mode and Pi-mode. Using this values and measured size of dumbbell we calculated the length part that we must cut off for getting optimal frequency. All measured and calculated data presented in table below and noted in database.

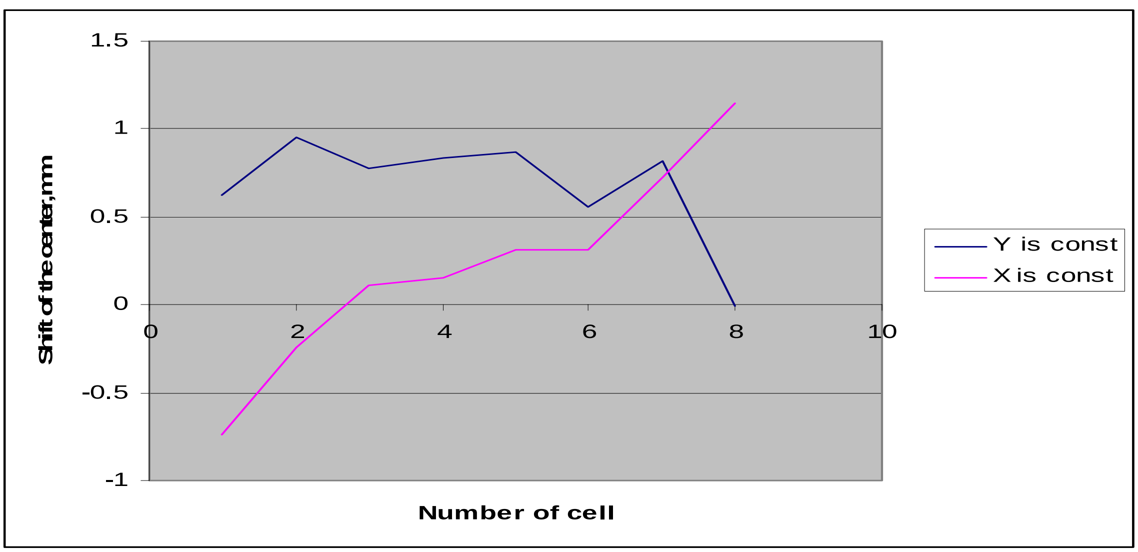
C1	C2	Fmeas	dF	Fcalc	Lmeas	Cut, mm	Tun, mm	Cut, "
163		3861.64	0.1	3861.61	39.829	0.413	0.138	0.0163
	188			3861.67		0.412	0.139	0.0162
164		3860.76	-4.8	3862.69	39.888	0.415	0.165	0.0164
	186			3858.84		0.452	0.129	0.0178
165		3861.90	1.5	3861.32	39.806	0.411	0.129	0.0162
	177			3862.49		0.400	0.140	0.0157
166		3861.62	-2.1	3862.48	39.828	0.405	0.146	0.0159
	189			3860.77		0.421	0.130	0.0166
167		3860.97	-0.4	3861.13	39.843	0.421	0.137	0.0166
	168			3860.82		0.423	0.135	0.0167
170		3863.50	1.4	3862.94	39.887	0.413	0.167	0.0163
	171			3864.06		0.402	0.178	0.0158
172		3863.61	1.9	3862.86	39.855	0.407	0.157	0.0160
	173			3864.37		0.392	0.172	0.0155
174		3861.89	-2.1	3862.74	39.827	0.402	0.148	0.0158
	178			3861.04		0.418	0.132	0.0165
175		3862.19	-2.5	3863.18	39.857	0.404	0.161	0.0159
	176			3861.20		0.423	0.142	0.0166
179		3863.22	-0.1	3863.26	39.867	0.406	0.165	0.0160
	182			3863.19		0.406	0.164	0.0160
180		3861.38	1.1	3860.94	39.815	0.416	0.128	0.0164
	187			3861.82		0.408	0.136	0.0161
183		3863.53	-0.3	3863.65	39.861	0.401	0.166	0.0158
	184			3863.42		0.403	0.164	0.0159
185		3861.17	2.9	3860.03	39.889	0.441	0.140	0.0174
	197			3862.31		0.419	0.162	0.0165
191		3861.67	0.3	3861.56	39.826	0.413	0.137	0.0163
	198			3861.79		0.411	0.139	0.0162
192		3862.56	-1.8	3863.27	39.929	0.419	0.182	0.0165
	193			3861.84		0.432	0.169	0.0170
195		3861.79	-0.8	3862.12	39.901	0.424	0.164	0.0167
	196			3861.46		0.430	0.157	0.0169

IV. Calculations of the electromagnetic center of cells in cavity using bead-pull measurements.

When 9 niobium dumbbells are tested and trimmed they are going to be welded in one cavity using electron beam. There could be also some mechanical asymmetry. To find out them we need no calculate the electromagnetic center of cells in cavity. We used bead-pull technique. It means that we pulled little disturb metal ball through the cavity and measured phase of transmitted electromagnetic wave on working mode (Pi-mode). Then we shifted axis (axis Z) on which the disturbance element was moving in one X direction and did similar bead-pull measurements and did same for Y direction. Then we calculated the deviation of electromagnetic center on the iris and on equator of each cell. The graph was plotted in accordance with results.



Graph 3 Shift of electromagnetic center on the equator of cell.



Graph 4 Shift of electromagnetic center on the iris of cell.

All this measurements was made manually and took long time, so it is necessary to automate all this work. I started to write the program which would make all calculations automatically. But I don’t have enough time to finish it.

V. Conclusion

As we see from the graphs we have got, the stiffness coefficient of cavity is depends of temperature and it would be better to make same experiment again at conditions that would be at ILC.

Calculating the electromagnetic center of cells in cavity using bead-pull technique gives us results with high precision.

VI. References

1. “TESLA: The superconducting electron-positron linear collider with an integrated X-ray laser laboratory. Part II The accelerator.”
2. I..S.Gonorovsky. “Basis of radiotechnics.”
3. National Instruments. LabView.